Antarctic Mosses

Literature Review for Graduate Certificate on Antarctic Studies 2001-02

Gateway Antarctica, University of Canterbury

Dr. Lars Brabyn
Department of Geography
University of Waikato.

Abstract:

A literature review on Antarctic mosses was undertaken to identify the types of mosses found in Antarctica and the main environmental determinants of their habitats. This information was then discussed in relation to constructing a Geographical Information System habitat model. Mosses reproduce asexually in Antarctica because of the harsh conditions therefore endemism is unlikely. The main limiting determinants of habitat are factors such as temperature, available moisture, exposure to solar radiation and wind, and soil type. The main habitats are in Antarctic Peninsula, Ross Island, and coastal seasonally ice free areas. Mosses are more sensitive than lichens and cyanobacteria to climate change and therefore are a good indicator of global climatic change. Many of the determinants of moss habitat can be represented in a Geographical Information System.

The Antarctic Environment

Antarctica has an extremely cold, dry and inhospitable climate, but nevertheless, some plants do manage to survive in isolated areas in the dry valleys, the Antarctic peninsula, the offshore islands and along parts of the coastline. The amount and variety of vegetation in Antarctica is limited by several factors, namely, temperature, available light, nutrients, and available water. As the Antarctic climate is so extreme, all plant species are frost tolerant, with some being able to photo-synthesise at temperatures below freezing. Access to nutrients for terrestrial plants is problematic, because in those areas where the soil is permanently, or seasonally exposed, the available water is very limited in such an arid climate. Sufficient available light for photo-synthesis is limited to the Summer months, and for most species, growth within this brief period is further constrained by snow cover, which may not melt until mid-Summer.

Mosses

This literature review focuses on mosses as a possible tool in detecting both past and future climate change. Although not as widespread as algae or even lichens, mosses are represented in Antarctica by several species; *Bryum a/gens, antarcticum, argentium, Sarconeurum glaciale.* In contrast to algae, lichens, and cyanobacteria, mosses are perhaps more sensitive to climatic variation, particularly changes in temperature and precipitation.

The isolation of colonies of Antarctic mosses to separate ice-free areas has not resulted in sub-speciation characteristic of island environments in warmer islands.

This is because the harsh Antarctica climate pre-disposes most flora toward asexual reproduction, which limits genetic variation within the species. Thus, the recognition of endemic taxa in Antarctica is contentious. Longton (1988, 30) is sceptical that there is any endemism: "Of the species apparently confined to these areas, the majority are doubtfully distinct members of different genera such as Bryum and Ceratodon" .

Literature Review Related to Antarctic Mosses

There has been few publications specifically devoted to mosses on the Antarctic continent. Nevertheless, some of the more general research provides useful information on the distribution and environmental constraints on polar bryophites.

Longton (1988) focuses on not only both mosses and lichens, but the geographic extent of the study includes both Arctic and Antarctic environments. In the Antarctic region, the study extends to the offshore islands and out to, and beyond the Antarctic Convergence to encompass the Macquarie, Crozet, Falkland and Fuegian Islands. The author divides polar environments into four categories (mild, cool, cold, frigid) in order to compare the two polar temperature regimes, but only the' 'frigid" regime applies to continental Antarctica. Longton discusses the various constraints to the growth of Antarctic mosses, including temperature, moisture, solar radiation, nutrients, competition and mechanical damage from wind and grazing. A further limiting factor, which applies much more to Antarctic, rather than Arctic environments, is the paucity of routes of colonisation or re-colonisation of species, by way of terrestrial dispersion (Longton, 1988, 30 & 325-326).

Smith (1994) studied vascular plants (rather than mosses) on the Argentine Islands as bioindicators of possible warming in the Antarctic region. There are only two native vascular plants on the continent (*Co/obanthus quitensis and Deschampsia antarctica)* and these may be a more sensitive indicator of change than non-vascular species, such as mosses. The study, conducted between 1964 and 1990, concluded that the peripheral Antarctic environment seems to be warming (Smith, 1994, 326-327). While increasing temperatures would also be conducive to the growth of mosses, it is not clear what other factors associated with climate change, such as available moisture and plant competition would have on the distribution of mosses in this environment.

The study by Moorhead and Priscu (1998) centres on the environment of the McMurdo dry valleys. The vegetation examined seems to be confined to mats of cyanobacteria in some of the streams of glacial melt-water which flow into the valleys. No mention is made of mosses, and it seems unlikely that this environment would be suitable for the growth of bryophites: Although the ground would be largely ice-free, the mosses are sensitive to drying out and there would be little available water for terrestrial plants during the short growing season (the annual precipitation is under 1Ocm, falling as snow in winter (Moorhead and Priscu, 1998, 352)).

Kappen (2000) focuses on the apparent competitive advantage that Lichens have in certain parts of Antarctica. Unlike the mosses, lichens are capable of a feeble photo-synthesis at sub-zero temperatures, such as while under a light covering of snow (Kappen, 2000, 316-319). Furthermore, the lichens are also more capable of surviving desiccation and fare better than mosses in drier environments (Kappen,

2000, 321). In the arid environment of Antarctica, this relative advantage is reflected in the number of endemic species of lichen (estimated at between 30-80%, Kappen, 2000, 321) compared to that of mosses (estimated at 7%, Kappen, 2000, 321).

The study by Howard-Williams, Pridmore, Broady, & Vincent (1990) concerns cyanobacteria in ponds formed on the McMurdo ice shelf and represents an environment which is most unlikely to support the growth of mosses.

Broady (1989) studied three seasonally ice-free environments adjacent to the Antarctic continent (Capes Bird, Royds and Crozier on Ross Island). When the sea-ice breaks up, the catabatic winds drive a considerable amount of seas-spray on to the adjacent land, and the amount of saline aerosols in this region affected the growth of all flora. Mosses were found in scattered patches at all three sites, and the limiting factors seemed to be moisture (mosses were not present above a free-draining sub-stratum), wind (most clumps were found on slopes with a north-easterly aspect, away from the prevailing south-easterly winds), and salinity (moss clumps were not found in areas with high salinity caused by sea-spray, or concentrations of penguin droppings). Despite the mosses' intolerance of high salinity, they are relatively tolerant of moderate levels, compared to that of lichens, and thus have a competitive advantage in areas with sufficient moisture. Isolated cushions of mosses were found up to 900m, but most were confined to elevations of less than 300m (Broady, 1989, 93): The constraint of elevation would represent lower temperature, less available moisture, and greater wind exposure with increasing height above sea level.

Vestal (1993) describes the difficulties of any colonising flora in establishing in Antarctica, including the extremely short metabolically active periods each year. Any study of plant succession would therefore have to operate on a much longer time-scale to that of more temperate climates.

Walton (1993) mentions the part played by mosses in trapping mineral particles washed down by Antarctic snow-melt. As well as providing a source of nutrients, the entrapped fine particles help to provide a stable and weighty base to resist the clump being swept away by wind or water.

Constructing a GIS model for Antarctic mosses

Several factors determine the location and abundance of Antarctic mosses, and at least some of them may be determined indirectly using existing remote sensing and cartographic data.

Latitude

Mosses are at the limit of their environmental range in Antarctica, and their prevalence, and diversity decreases with increasing latitude.

Ice/Snow Cover

All areas with permanent ice cover can be eliminated as potential locations for mosses. Unlike the Algae or Lichens, Mosses do not photo-synthesise at sub-zero temperatures, so all those areas which do not have at least several months of

above-zero temperatures, and which do not have a similar period of no ice/snow cover can be eliminated as possible habitats.

Soil/Rock Colour

Periodically ice-free areas with a dark soil colour will retain more solar heat during summer and would be more likely to provide a suitable environment. Areas with high albedo can therefore be eliminated as potential locations.

Soil/Rock Structure

Mosses have a rudimentary root system, which limits their access to nutrients and their ability to anchor themselves to the substrate. While the immediate access to nutrients can be a factor during initial colonisation, the clump-like structure of established mosses usually allows the accumulation of small particles around the base of the colony, which helps to stabilise the clump by weight, rather than by anchoring with a deep root structure. These limitations in this taxa's ability to anchor the clumps leaves them vulnerable to uprooting by the strong catabatic winds. Unlike the lichens, mosses do not appear to cause a significant amount of mechanical and chemical breakdown of their mineral substrate (Walton, 1993, 40-46). This factor would appear to predispose the mosses to either a soil/rock structure with pre-existing cracks in which to anchor, and/or to a location which was protected from winds. However, many sheltered locations would also receive less solar energy because of shading, and would therefore not provide suitable growing conditions. A criteria for suitable shelter from wind damage would be a

moderate North-facing slope *without* other adjacent land masses to obscure the summer sunlight.

Moisture

Unlike Lichens, Mosses cannot survive drying out, so areas which experience arid conditions during the summer months, such as the dry valleys, can also be largely eliminated. In this environment, local colonies of mosses may exist where streams of melt-water provide a sufficiently stable source of moisture.

Salinity

The growth of Mosses is inhibited by high salt levels, and the study by Broady (1989, 79-80 & 93) shows that those coastal areas which face South over a body of seasonally open sea will receive a significant amount of wind-borne salt spray generated by the catabatic winds, these areas can also be ruled out as possible habitats for mosses. Broady's study also shows that high levels of salinity are generated by penguin rookeries (1989, 80). Nevertheless, mosses are more tolerant of moderate levels of salinity than lichens.

Other Factors

Other factors which may determine the distribution of mosses may be more difficult to deduce from remotely-sensed data. Competition from other flora, such as the Bryophitic lichens, may represent either an overall competitive advantage, or the success of these lichens may be an artefact of climatic fluctuations. Lichens would

have an advantage over mosses in colder and drier conditions, and as Antarctic mosses tend to replicate asexually, they would not have a local bank of reserve spores with which tore-colonise areas after adverse short-term fluctuations in temperature and moisture levels. Furthermore the paucity (or absence) of endemic species could mean that any adaptation to local environmental conditions by mosses is either impossible, or at least, unproductive (i.e., mosses may be simply incapable of *any* modification which would improve their survival in this harsh environment). The present distribution of mosses may reflect, to some extent, the distance from reserve sources of potential vegetative colonists, i.e., distance from nunataks, and the milder environments of the off-shore islands and the Antarctic peninsula.

Mosses as Climatic Artefacts

A model constructed on present-day environmental variables may predict with some degree of certainty where mosses are likely to be found in Antarctica. No doubt, there would be exceptions, because of factors which are difficult to model, but in such an extreme environment, even a single contra-indicating factor would probably be enough to prevent the local establishment of mosses. Conversely, the *actual* location of mosses (and other flora) on the Antarctic mainland could be used to extrapolate past climatic history. Given the marginal growing conditions for most flora; the constraints on seed and spore production and dispersal; the limited animal grazing and disturbance; and the rate of vegetative growth during the short growing season, useful speculations could be made about relatively recent and subtle fluctuations in climatic conditions. The rate of re-establishment would be

much slower than in more benign climates and the sources of re-colonisation are very limited, so historic modelling would seem more feasible.

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